Local competition increases people's willingness to harm others: supplementary material

1. Illustrative game theoretic model

Consider n individuals, each of whom has r resources, competing over a bonus resource b. Each individual interacts with one social partner, and can use an amount x of her r resources to reduce that partner's resources by kx (that is, strategy x is the investment in costly harming). An individual's payoff is the amount of resources she has left after harming her partner and being harmed in turn by that same partner. An individual's fitness is determined by her own payoff plus the bonus that she gets if she wins the competition with n-1 competitors. The probability that a player wins the bonus is determined by the ratio of her payoff to the sum of all n individuals' payoffs (i.e. her own payoff plus her partner's plus n-2 others'). Competition is extremely local when n=2, such that an individual's payoff is only compared with that of her partner, and life is a zero-sum competition between them. As n increases, the scale of competition becomes increasingly global, and an individual's payoff is compared with n-2 competitors' in addition to her partner's.

What investment in costly harming (x) maximizes fitness, and how is it affected by the scale of competition (n)? To answer this, we consider a focal actor who invests x in harming a social partner, and whose n-1 competitors invest x_{pop}. The focal actor's payoff is r-x-kx_{pop}, while her partner's payoff is r-x_{pop}-kx, and the payoff of each of the n-2 players who do not interact with the focal actor is r-x_{pop}-$k\,x_{pop}$. The fitness, w, of this focal individual is her own payoff plus the expected reward from winning the competition for the bonus b:

$$w = \left(r - x - kx_{pop}\right) + b\,\frac{\left(r - x - kx_{pop}\right)}{\left(r - x - kx_{pop}\right) + \left(r - x_{pop} - kx\right) + (n-2)\left(r - x_{pop} - kx_{pop}\right)} \tag{1}$$

Please note that we constrain payoffs to be greater than zero, so that individuals cannot have negative fitness. Please note also that the ratio of the focal individual's payoffs to her competitors' payoffs does not necessarily assume that the focal individual receives a *proportion* of the bonus; rather, it can also represent the probability that the focal individual receives the *entire* bonus.

We seek the value of x and x_{pop} that maximizes fitness, which we denote x*. When fitness is at a maximum, $\frac{dw}{dx}$=0 and $\frac{d^2w}{dx^2}$<0. Thus, to find x*,we differentiate w with respect to x, set x=x_{pop}=x*, and solve $\frac{dw}{dx}$=0 for x*.

$$\frac{dw}{dx} = \frac{k+1-n}{n^2(r-(k+1)x^*)} - 1 = 0 \tag{2}$$

This gives the following solution: $x^* = \frac{b(n-1-k)+n^2 r}{(1+k)n^2}$. As we constrain payoffs to be positive, x^* must satisfy r-x^*-kx^*>0, i.e. $x^* < \frac{r}{(k+1)}$. The above expression for x^* satisfies this condition when $n<k+1$.

To check whether this expression for x^* yields a fitness maximum, we substitute it into the second derivative $\frac{d^2w}{dx^2} = \frac{2b(1+k)(1+k-n)}{n^3(r-(1+k)x^*)^2}$, and see when the second derivative is negative:

$$\frac{d^2w}{dx^2} = \frac{2(1+k)n}{b(1+k-n)} < 0 \tag{3}$$

This is negative when $n>k+1$. However, given that payoffs must not be negative (r-x^*-kx^*>0), we can only consider values of x^* for which $n<k+1$, as shown above. Thus, there are no conditions in this model under which this expression for x^* satisfies both $\frac{dw}{dx} = 0$ and $\frac{d^2w}{dx^2} < 0$), and so this expression for x^* is not a fitness maximum. Instead, we need to consider the cases where $\frac{dw}{dx} > 0$ and where $\frac{dw}{dx} < 0$ to determine the fitness-maximizing investments in harming.

When $\frac{dw}{dx} > 0$, one's fitness increases as one invests more in harming, which means that individuals maximize their fitness by investing as much as they can in harming (i.e., $x^* \rightarrow \frac{r}{(k+1)}$, since we require r-x^*-kx^*>0 (payoffs are not negative)).The derivative $\frac{dw}{dx}$ is greater than zero when $n<k+1$. That is, people are more likely to invest everything in harming when there are fewer competitors (lower n: local competition) and when harming is more effective (higher k). When $\frac{dw}{dx} < 0$, one's fitness decreases as one invests more in harming, which means that individuals maximize their fitness by investing nothing in harming ($x^*=0$). The derivative $\frac{dw}{dx}$ is less than zero when $n \geq k+1$, i.e. when there are more competitors (higher n: global competition) and harming is less effective (lower k).

To summarize, the model predicts that when an individual has fewer competitors (competition is local), she is should be more willing to spend all her resources on harming her partner. As the number of competitors increases (i.e. increasingly global competition), an individual should become less willing to incur any cost to harm her partner. We note that behavior in economic games often deviates from precise game theoretical predictions (Burton-Chellew & West, 2012), so we do not predict that our participants will spend exactly zero on harming under global competition and their entire endowments on harming under local competition. Instead, the relevant predictions are comparisons of the relative amounts spent under local versus global competition, not the absolute amounts (Barker, Barclay, & Reeve, 2012; Burton-Chellew & West, 2012; Kümmerli, Burton-Chellew, Ross-Gillespie, & West, 2010).

References

Barker, J. L., Barclay, P., & Reeve, H. K. (2012). Within-group competition reduces cooperation and payoffs in human groups. *Behavioral Ecology*, *23*(4), 735–741. doi:10.1093/beheco/ars020

Burton-Chellew, M. N., & West, S. A. (2012). Pseudocompetition among groups increases human cooperation in a public-goods game. *Animal Behaviour*, *84*(4), 947–952. doi:10.1016/j.anbehav.2012.07.019

Kümmerli, R., Burton-Chellew, M. N., Ross-Gillespie, A., & West, S. A. (2010). Resistance to extreme strategies, rather than prosocial preferences, can explain human cooperation in public goods games. *Proceedings of the National Academy of Sciences of the United States of America*, *107*(22), 10125–10130. doi:10.1073/pnas.1000829107

2. Study 4: number of competitors versus number of partners

In Studies 1-3 in the main text, we implemented the scale of competition in the same way, by changing the number of competitors for the bonus prize (under local competition, people competed with others in their own group of three but not with members of the two other groups of three, while under global competition, people competed with members of all three groups in the session). However, a key difference between Study 3 versus Studies 1 and 2 was the number of people that each player could harm (social partners or recipients). In Studies 1 and 2, people could only harm others in their own group of three partners, whereas in Study 3, people had the opportunity to harm any player in the room, regardless of which group of three they were in. Therefore in Study 4 we sought to investigate whether changing the number of partners that can be harmed changes people's willingness to invest in harming them.

2.1. Study 4 methods

This study took place at the University of Guelph, Canada, under the same conditions as Study 3 described in the main text, with differences as follows.

Each player had a CAN$5 endowment, any amount of which she could spend on making others lose three times that amount (i.e. a harming factor of three). Each session consisted of four players, assigned to two groups of two (henceforth “dyads”). In dyad conditions, a player could only harm and be harmed by the other player in her own dyad. In tetrad conditions, a player could harm and be harmed by all three other players in the session. That is, the number of social partners varied between dyad and tetrad conditions. We referred to players within a given dyad as “ingroup members” and players in the other dyad as “outgroup members”, and repeatedly told participants who their “group members” were, but there was no other manipulation of group membership because ingroup/outgroup effects were not our prime interest in this study.

Players competed over two CAN$5 bonus prizes. In local competition conditions, one prize was awarded to the highest earner in each dyad (i.e. players in each dyad competed for the prize with each other but not with members of the other dyad). In global competition conditions, two highest earners in the session of four people each received a prize (i.e. players competed for the prizes with members of their own dyad as well as with members of the other dyad). That is, the number of competitors varied between local and global competition conditions.

We used a full-factorial design with respect to the scale of competition (number of competitors) and number of partners (dyad or tetrad). That is, we ran four experimental conditions: partner dyads with local competition (5 sessions), partner dyads with global competition (6 sessions), partner tetrad with local competition (5 sessions), and partner tetrad with global competition (5 sessions); the uneven number of sessions is because there were insufficient participants to have an equal number of sessions in all conditions. Thus 21 sessions in total with four participants each gave a total of 84 participants (70 female and 14 male; mean age 18.24 years ± s.e. 0.09 years). Participants in each session played only one of the four experimental conditions (that is, a between-subjects design).

We predict that, when comparing between conditions, people will increase their burning of competitors but not of non-competitors. In local competition conditions, one's only competitor is the member of one's own dyad (ingroup member), whereas the members of the other dyad (outgroup members) are not competitors. In global competition, one competes with all participants in the session (two outgroup members in the other dyad, and the ingroup member of one's own dyad). As the number of competitors does not change between the dyad and tetrad conditions, we do not expect the total amounts spent on burning to change between these conditions. However, as the number of partners does change between these conditions, we expect the amount spent on burning per partner to change. That is, when there are more partners (tetrad conditions), people should spend less on burning each partner than when there are fewer partners (dyad conditions). We analyzed the results with ANOVAs and *t*-tests conducted on IBM SPSS Statistics 23.

2.2. Study 4 results and discussion

People spent significantly more overall (regardless of the scale of competition) on burning the other person in their dyad (ingroup members) than people in the other dyad (outgroup members) ($F_{1,80}$=20.43, p<0.001), and there was a significant interaction between group membership of the victim (ingroup versus outgroup member) and the number of partners (dyad versus tetrad conditions) ($F_{1,80}$=11.13, p=0.001). These results are trivial artefacts of that fact that participants could only burn ingroup members in the dyad conditions.

When comparing the burning of ingroup members in dyad versus tetrad conditions, people spent marginally more on burning ingroup members in dyads than in tetrads ($F_{1,80}$=3.31, p=0.072; mean ± standard error: dyads \$0.36 ± \$0.07, tetrads \$0.21 ± \$0.07). This effect is probably because the burning of ingroup members was slightly diluted by the opportunity to burn outgroup members in the tetrad conditions. People spent more on burning ingroup members when competition was local than when it was global ($F_{1,80}$=4.46, p=0.38; mean ± standard error: local competition \$0.40 ± \$0.07, global competition \$0.19 ± \$0.07). There was no interaction between the scale of competition and the number of partners one could burn (dyads versus tetrads; $F_{1,80}$=0.813, p=0.37).

For our primary analysis of the scale of competition, there was a significant interaction between the scale of competition (local versus global) and the target of the money-burning (ingroup member versus outgroup member) ($F_{1,80}$=6.36, p=0.014). We need to analyze the dyad and tetrad conditions separately because only ingroup members could be targeted in the dyad conditions.

When participants could only burn their immediate social partner (ingroup members only; dyad conditions), the scale of competition did not significantly affect how much they spent on burning that partner in the full sample (t_{42}=0.763, p=0.45; mean ± standard error: local competition \$0.44 ± \$0.13, global competition \$0.33 ± \$0.09). However, this effect becomes significant when we exclude participants who apparently did not understand the game and spent money burning themselves, such that people burn their partner more under local competition than under global competition (one-tailed t_{29}=1.78, p=0.042, d=0.65; mean ± standard error: local competition \$0.43 ± \$0.13, global competition \$0.17 ± \$0.05); a one-tailed test is justified based on the results of Studies 1-3.

When participants could burn anyone (tetrad conditions), the scale of competition affected whether people burned ingroup members or outgroup members more (interaction $F_{1,38}$ = 10.39, p=0.003). An examination of this interaction revealed that burning of ingroup members is higher with local competition than with global competition ($F_{1,38}$=6.70, p=0.0140; mean ± standard error: local competition \$0.35 ± \$0.11, global competition \$0.06 ± \$0.03), whereas burning of outgroup members is marginally higher with global competition than with local competition ($F_{1,38}$=3.03, p=0.090; mean ± standard error: global competition \$0.19 ± \$0.04, local competition \$0.11 ± \$0.03). Another way to look at that interaction is to test who participants target at different scales of competition: participants experiencing global competition burned each outgroup member more than they burned their ingroup member ($F_{1,19}$=10.80, p=0.004; mean ± standard error: ingroup member \$0.06 ± \$0.03, each outgroup member \$0.19 ± \$0.04), whereas participants experiencing local competition burned their ingroup member (i.e., their competitor) more than they burned each outgroup member ($F_{1,19}$=5.02, p=0.037; mean ± standard error: ingroup member \$0.35 ± \$0.11, each outgroup member \$0.11 ± \$0.03). These different analyses all show that local competition with ingroup members results in people spending more to burn those ingroup members.

To summarize, Study 4 shows that, as predicted, the changes in people's willingness to burn under different scales of competition reflect changes in who their competitors are (ingroup members only when competition is local versus ingroup *and* outgroup members when competition is global). Changing the number of partners who can be burned (from ingroup members only in the dyad conditions to ingroup *and* outgroup members in tetrad conditions) is only relevant when the new partners who can be burned are also competitors (i.e. outgroup members when competition is global), and means that people spread a given amount spent on burning among more competitors.

3. Parametric statistics from main text

Because our data were not normally distributed and had unequal variances, we used non-parametric statistics and presented the medians and interquartile ranges in the main text. For reference, we present the parametric statistics below. The results are qualitatively the same as for the non-parametric statistics.

3.1. Study 1

Participants spent significantly more on burning each group member's money under local competition than global competition (t-test: t_{52}=2.9219, p= 0.0052; mean ± standard error: local competition \$1.37 ± \$0.16, global competition \$0.77 ± \$0.13). Earnings from endowments were significantly lower in the local competition condition than the global competition condition (t-test: t_{52}=4.4797, p=0.0001; mean ± standard error: local competition \$0.22 ± \$0.14, global competition \$3.44 ± \$0.70).

3.2. Study 2

Participants spent significantly more on burning each group member's money under local competition than global competition (t-test: t_{34}= 4.9982, p<0.0001; mean ± standard error: local competition \$1.36 ± \$0.18, global competition \$0.36 ± \$0.09). Earnings from endowments were significantly lower in the local competition condition than the global competition condition (t-test: t_{34}=8.7369, p<0.0001; mean ± standard error: local competition \$0.50 ± \$0.25, global competition \$6.37 ± \$0.63).

3.2.1. Comparison of Studies 1 and 2

When competition was global, participants spent significantly less on burning each group member's money when they earned their endowments in Study 2, rather than were given their endowments in Study 1 (t-test: t_{43}=2.5501, p=0.0145). However, there was no difference in the amounts spent on burning in each study when competition was local (t-test: t_{43}=0.057, p=0.9549).

3.3. Study 3

People spent significantly more on burning each other person's money when competition was local than when it was global (t-test: t_{70}=3.5558, p=0.0009; mean ± standard error: local competition \$2.44 ± \$0.41, global competition \$0.81 ± \$0.14). This resulted in lower earnings when competition was local versus global (t-test: t_{70}=7.2417, p<0.0001; mean ± standard error: local competition \$1.80 ± \$0.51, global competition \$5.99 ± \$0.26).

The higher burning under local versus global competition was due to increased burning of each ingroup member's money (t-test: t_{70}= 3.7698, p=0.0006; mean ± standard error: local competition \$0.87 ± \$0.16, global competition \$0.09 ± \$0.03). There was no change in burning each outgroup member's money under local versus global competition (t-test: t_{70}= 0.2225, p= 0.8246; mean ± standard error: local competition \$0.09 ± \$0.03, global competition \$0.10 ± \$0.35).

Participants spent significantly more on burning ingroup members' money than outgroup members' when competition was local: this is true whether we analyze the total spent on burning ingroups and outgroups (t-test: t_{70}= 2.69, p=0.0099; mean ± standard error: ingroup members \$1.73 ± \$0.32, outgroup members \$0.56 ± \$0.18) or the amount spent burning each individual ingroup or outgroup member (t-test: t_{70}= 3.786, p=0.0006). By contrast, when competition was global, participants spent significantly more in total on burning outgroup members' money than ingroup members' (t-test: t_{70}= 2.7503, p=0.0082; mean ± standard error: ingroup members \$0.19 ± \$0.10, outgroup members \$0.61 ± \$0.10), but there was no difference in the amount spent on burning per person under global competition (t_{70}= 0.2038, p=0.8392).